Deutsches Institut für Bautechnik
DIBt

Approval body for construction products and types of construction

Bautechnisches Prüfamt

An institution established by the Federal and Laender Governments

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European Technical Assessment

ETA-08/0002 of 23 January 2018

English translation prepared by DIBt - Original version in German language

General Part

Technical Assessment Body issuing the European Technical Assessment:	Deutsches Institut für Bautechnik
Trade name of the construction product	VBT-KI 4 to 19
Product family to which the construction product belongs	PAC 16, Post-Tensioning kits (internal bonded for strands)
Manufacturer	Gleitbau Ges. m.b. H. VBT-Systems Itzlinger Hauptstraße 105 5020 SALZBURG ÖSTERREICH
Manufacturing plant	Gleitbau Ges. m.b. H. VBT-Systems Itzlinger Hauptstraße 105 5020 SALZBURG ÖSTERREICH
This European Technical Assessment contains	28 pages including 21 annexes which form an integral part of this assessment
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of	European Assessment Document EAD 160004-00-0301

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Specific part

1 Technical description of the product

1.1 Definition of the construction product

The present European Technical Assessment applies to the post-tensioning kit for prestressing of structures with the trade name:

VBT-KI 4 to 19

consisting of 4 to 19 strands with nominal tensile strength 1770 MPa or 1860 MPa (Y1770S7 or Y1860S7 according to prEN 10138-3:2009-08, Table 4), nominal diameter 15.7 mm (0.62" - 150 mm²) which are used in normal-weight concrete with the following anchorages (stressing and fixed anchorages and couplers):

1. Stressing (active) anchorage and fixed (passive) anchorage Type P with anchor plate and anchor block for tendons of 4, 7, 9, 12, 15 and 19 strands,
2. Stressing (active) anchorage and fixed (passive) anchorage Type M with cast-iron anchor body and anchor block for tendons of 9, 12, 15 and 19 strands,
3. Fixed Couplers Type B (bolts) for tendons of 4, 7, 9, 12, 15 and 19 strands,
4. Movable Couplers Type B (bolts) for tendons of 4, 7, 9, 12, 15 and 19 strands.

Additional components of the present Post-Tensioning system are:

5. Splitting tensile reinforcement (Helixes and additional reinforcement),
6. Ducts,
7. Corrosion protection.

The anchorage of the strands in wedge plates and couplers is done by means of wedges.

The components and the system setup of the product are given in Annex A.

1.2 Strands

Only 7-wire strands shall be used in accordance with national provisions and the characteristics given in Table 1:

Table 1: Dimensions and properties of 7-wire strands

Designation	Symbol	Unit	Value
Tensile strength	R_m	MPa	1770 or 1860
Nominal diameter (strand)	d_p	mm	15.7
Nominal cross section (strand)	A_p	mm²	150
Nominal mass (strand)	M	g/m	1172
External wire diameter	D	mm	5.2 ± 0.04
Core wire diameter	d'	mm	1.02 to 1.04 d

To avoid confusion only strands with one tensile strength shall be used on one site.6

Only strands stranded in the same direction shall be used in a tendon. For further characteristic values of the strands see Annex A10.

1.3 Ring wedges

Ring wedges (see Annex A9) consisting of three parts are used. Single parts are fixed together by a spring ring.

Wedges of one supplier only may be used at one construction site.

1.4 Anchor blocks and couplers

The anchor blocks of stressing and fixed anchorages are identical. Determination is only needed due to execution of construction work.

Couplers with bolts have additionally drilled holes for the bolts.

The ring wedges of inaccessible fixed anchorages shall be hold in place by a retainer disc or by adequate pre-wedging.

The conical drills of the anchor blocks and couplers shall be clean, stainless and provided with corrosion protection grease.

1.5 Anchor plates

For 4 to 19 strands square anchor plates (type P) can be used (see Annex A4).

1.6 Cast-iron anchor bodies

For 9 to 19 strands multi-surface anchors (type M) can be used (see Annex A6).

1.7 Bolts

For couplers type B coatless threaded steel bolts according DIN EN ISO 4762 (formerly DIN 912) strength class 10.9 shall be used.

1.8 Splitting tensile reinforcement (Helixes and additional reinforcement)

The steel grades shall be B 500 B according to DIN 488: 2009. The dimensions of the helixes and of the additional reinforcement shall comply with the values given in the annexe A2. The central position in the structural concrete member on site shall be ensured according to Annex B1, section 3.3.

Each end of the helix shall be welded to a closed ring. The welding of the inner end of the helix can be omitted if the length of the helix is increased by 1½ additional turns.

1.9 Ducts, tubes and trumpets

Steel ducts in accordance with EN 523:2003 shall be used.

The trumpets at stressing, fixed anchorages and couplers (see Annexes A2, A4 and A6) are manufactured from 2.5 mm thick HDPE material.

If the trumpets are made of steel it is necessary to install a PE-pipe of at least 3.5 mm thickness and a length of 100 mm internally at the end of trumpet in the contact area with the strands to avoid the contact between strands and steel duct or steel connection duct in the buckling area.

Also corrugated plastic ducts which meet the requirements according to EAD 160004-00-0301 clause 2.2.10 and in accordance with regulations valid at the place of use can be used. Plastic ducts and the accompanying boundary conditions of use are not covered by this ETA-08/0002.

1.10 Grout

Grout according to EN 447:1996 shall be used.

1.11 Protection cap

Protection caps are made of plastic and fitted by screws onto the wedge plates.

2 Specification of the intended use in accordance with the applicable European Assessment Document

The performances given in Section 3 are only valid if the PT-System is used in compliance with the specifications and conditions given in Annex B.

2.1 Specification

Specific details for installation and use are given in Annex B1.

2.2 Useful life

The test and assessment methods underlying this ETA lead to the assumption of a useful life of least 100 years. This useful life information cannot be construed as a warranty of the manufacturer, but it is an aid in selecting the right products for the expected economically reasonably life of the work.

3 Performance of the product and references to the methods used for its assessment

No.	Essential characteristic	Performance
BWR 1: Mechanical restistance and stability		
1	Resistance to static load	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.1 is fulfilled, see Annex B1
2	Resistance to fatigue	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.2 is fulfilled, see Annex B1
3	Load transfer to structure	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.3 is fulfilled, see Annex B1
4	Friction coefficient	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.4 is fulfilled, see Annex C
5	Deviation/ deflection (limits) for internal bonded and internal unbonded tendon	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.5 is fulfilled, see Annex B1
6	Deviation/ deflection (limits) for external tendon	No performance assessed
7	Assessment of assembly	The acceptance criterion to EAD 160004-00-03-01 clause 2.2.7 is fulfilled
8	Resistance to static load under cryogenic conditions for applications with anchorage/coupling outside the possible cryogenic zone	No performance assessed
9	Resistance to static load under cryogenic conditions for applications with anchorage/coupling inside the possible cryogenic zone	No performance assessed
10	Material properties, component performance, system performance of plastic duct	No performance assessed

11	Material properties, component performance, system performance of plastic duct to provide an encapsulated tendon	No performance assessed
12	Material properties, component performance, system performance of plastic duct to provide an electrically isolated tendon	No performance assessed
13	Corrosion protection	No performance assessed
Monostrand, sheating base material		
14	Melt index	No performance assessed
15	Density	No performance assessed
16	Carbon black	No performance assessed
17	Tensile strenght	No performance assessed
18	Elongation	No performance assessed
19	Thermal stability	No performance assessed
Monostrand, manufactured sheating		
20	Tensile strenght	No performance assessed
21	Elongation	No performance assessed
22	Surface of sheating	No performance assessed
23	Environtal stress cracking	No performance assessed
24	Temperatur resistance	No performance assessed
25	Resistance to externally applied agents (mineral oil, acid, base, solvents and salt water)	No performance assessed
26	Sheating minimum thickness	No performance assessed
Monostrand, manufactured monostrand		
27	External diameter of sheating	No performance assessed
28	Mass of sheating per metre	No performance assessed
29	Mass of filling material per metre	No performance assessed
30	Alteration of dropping point caused by monostrand manufacturing	No performance assessed
31	Alteration of oil separation caused by monostrand facturing	No performance assessed
32	Impact resistance	No performance assessed
33	Friction between shealting and strand	No performance assessed
34	Leak tightness	No performance assessed

BWR 2: Safety in case of fire		
35	Reaction to fire	No performance assessed
BWR 3: Hygiene, health and the environment		
36	Content, emmission and/or release of dangerous substances	No performance assessed

4 Assessment and verification of constancy of performance (AVCP) system applied, with reference to its legal base

In accordance with the European assessment document EAD 160004-00-0301 the applicable European legal act is: [98/456/EC].

The system to be applied is: 1+

5 Technical details necessary for the implementation of the AVCP system, as provided for in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited with Deutsches Institut für Bautechnik.

Issued in Berlin on 23 January 2018 by Deutsches Institut für Bautechnik

BD Dipl.-Ing. Andreas Kummerow
Head of Department

beglaubigt:
Ascher

FIXED AND STRESSING ANCHORAGE

CAST-IRON ANCHOR

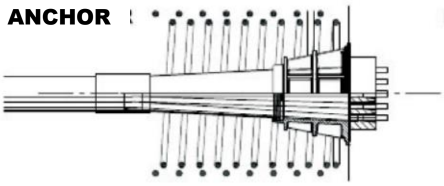
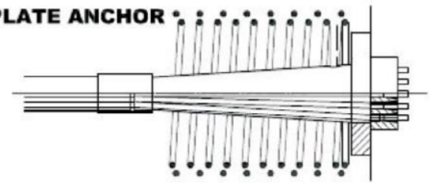
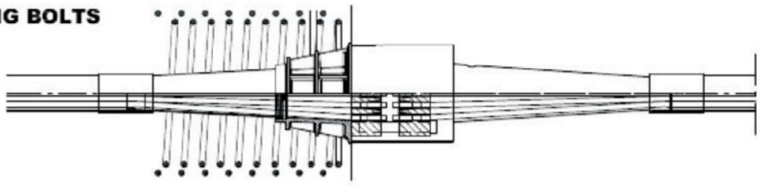


PLATE ANCHOR



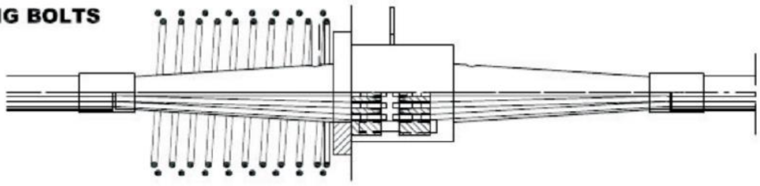
FIXED COUPLING - CAST-IRON ANCHOR

LAYOUT WITH COUPLING BOLTS



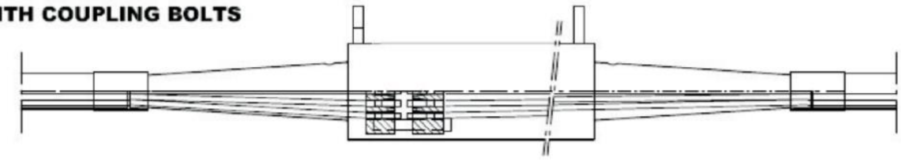
FIXED COUPLING - PLATE ANCHOR

LAYOUT WITH COUPLING BOLTS



MOVABLE COUPLING

LAYOUT WITH COUPLING BOLTS



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VBT-KI 4 to 19	Annex A1
Product description Overview anchorages and couplings	

Technical data of the anchorages

(figures see annexes A4 and A6)

System	VBT-KI 4		VBT-KI 7		VBT-KI 9		VBT-KI 12		VBT-KI 15		VBT-KI 19	
Number of strands	4		7		9		12		15		19	
Weight [kg/m]												
A_p = 150 mm² per strand	4.69		8.20		10.55		14.06		17.58		22.27	
Cross section area [mm²]												
A_p = 150 mm² per strand	600		1050		1350		1800		2250		2850	
Permitted prestressing force [kN]												
Steel strength f_{pk} [MPa]	1770	1860	1770	1860	1770	1860	1770	1860	1770	1860	1770	1860
A_p = 150 mm²												
Ultimate force F_{pk}	1062	1116	1859	1953	2390	2511	3186	3348	3983	4185	5045	5301
Max. overstr. force 0.95 $F_{p0.1k}$	866	912	1516	1596	1949	2052	2599	2736	3249	3420	4115	4332
Max. prestr. force 0.9 $F_{p0.1k}$	821	864	1436	1512	1847	1944	2462	2592	3078	3240	3899	4104
Anchor block												
Diameter [mm] ØRK	100		120		160		160		200		200	
Thickness [mm] H	45		50		55		60		75		75	
Anchor body (anchorplate, cast-iron anchor)												
Anchor type (P=anchorplate, M=cast-iron anchor)	P		P		P	M	P	M	P	M	P	M
Side length B (anchor plate) or max. outside diameter (cast-iron anchor) [mm]	170		210		245	Ø220	280	Ø220	320	Ø280	340	Ø280
Thickness [mm] D	20		30		35	180	40	180	45	210	50	210
Hole diameter at mounting surface [mm] ØL	70		88		124	124	124	124	155	152	155	152
Trumpet												
Length (after mounting) [mm] Lt	250		310		650	460	600	410	665	450	615	400
Duct diameter (inner / outer) [mm]												
Metal duct ØI/ØA	45/52		60/67		65/72		75/82		85/92		90/97	
Plastic duct ØI/ØA	59/73				76/91				100/116			
Minimum distance of anchorage (**) [mm]												
$f_{cm0.cube.150}$ ≥ 30 MPa (*)												
Center distance	225		300		340		390		440		490	
Edge distance (***)	103		140		160		185		200		225	
$f_{cm0.cube.150}$ ≥ 37 MPa (*)												
Center distance	210		270		310		370		410		460	
Edge distance (***)	95		125		145		175		185		210	
Helix												
Min. steel diameter [mm]	12		12		14		14		14 (16)		16 (14)	
Max. winding spacing [mm]	50		50		50		50		45 (50)		50 (40)	
Min. Length [mm]	175		275		300		325		425		475	
Outer diameter [mm]												
$f_{cm0.cube.150}$ ≥ 30 MPa (*)	190		260		300		320		360		410	
$f_{cm0.cube.150}$ ≥ 37 MPa (*)	160		230		270		320		350		390	
Additional reinforcement												
Bar diameter [mm]	5Ø12		5Ø14		6Ø14		7Ø14		8Ø14		8Ø14	
Bar spacing [mm] e	40		50		50		50		50		50	
Bar spacing b [mm]												
$f_{cm0.cube.150}$ ≥ 30 MPa (*)	205		280		320		370		400		450	
$f_{cm0.cube.150}$ ≥ 37 MPa (*)	190		250		290		350		370		420	

(*) Minimum actual concrete strength at stressing
(**) Distances can be reduced by 85 % of the given values in one direction, if increased correspondingly in the other direction.
(***) Concrete cover of helix and additional reinforcement shall be taken into account

VBT-KI 4 to 19	Annex A2
Product description Technical data of the anchorages	

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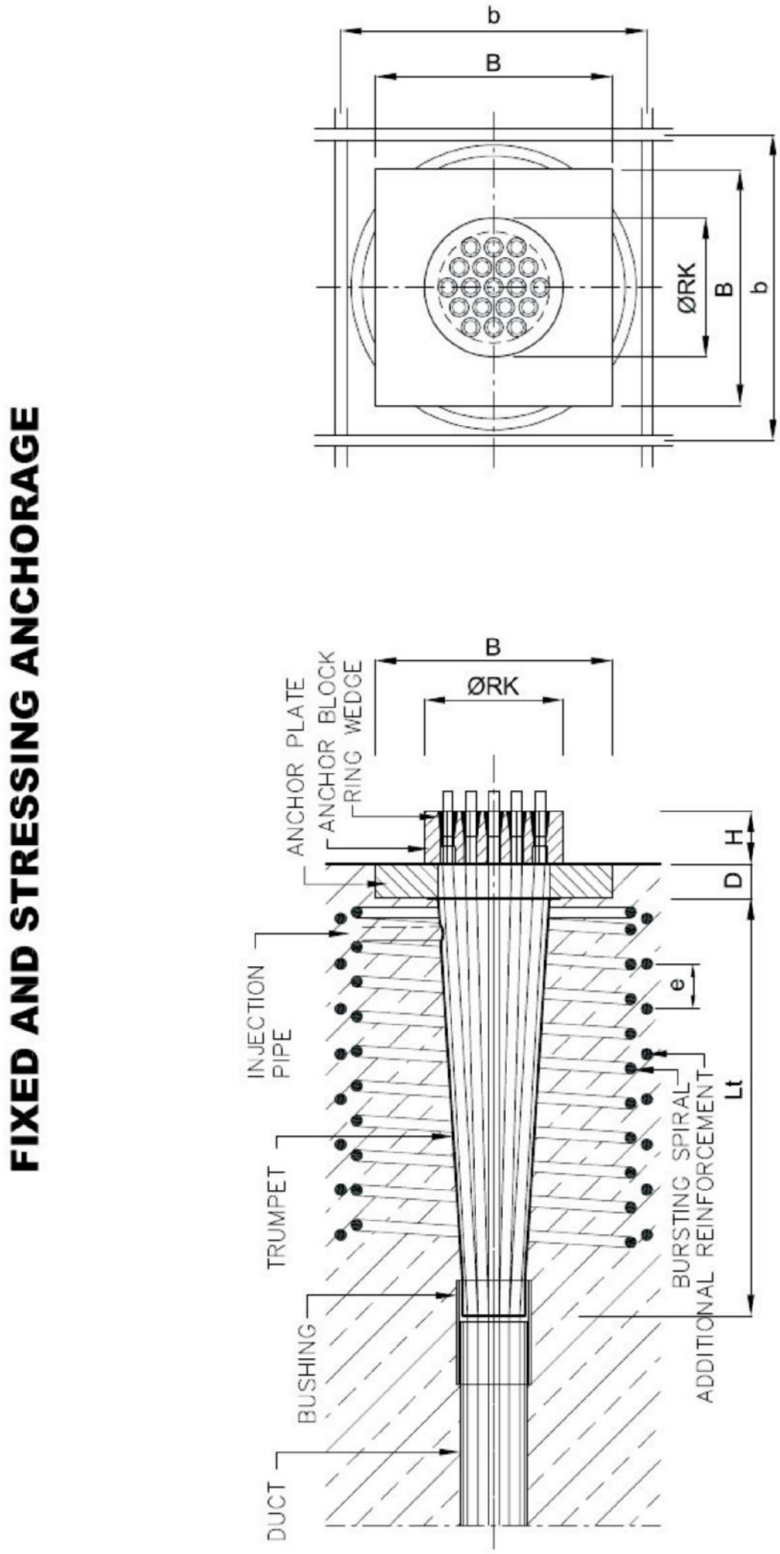
Technical data of the couplings

(figures see annexes A5, A7 and A8)

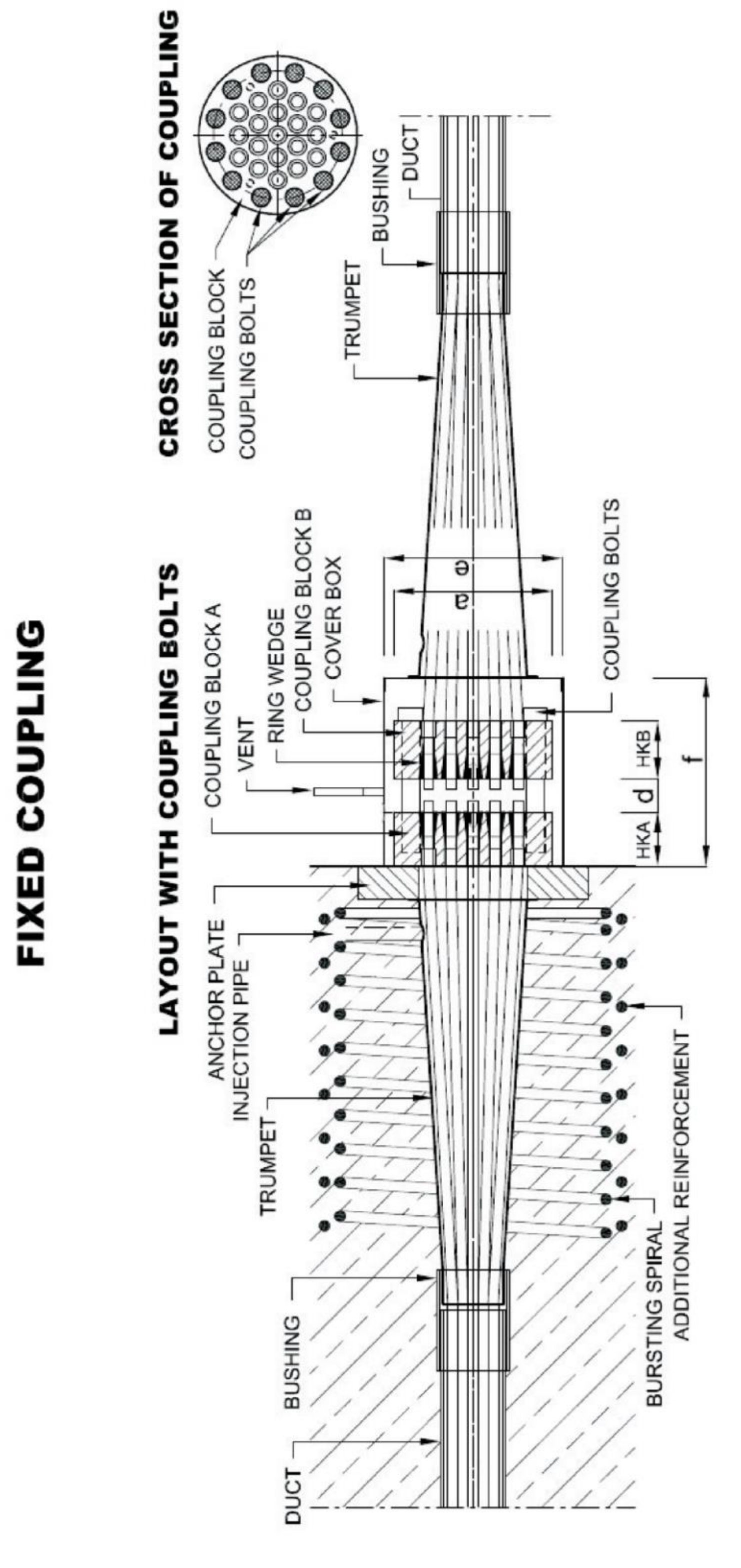
System		B4	B7	B9	B12	B15	B19
Number of strands		4	7	9	12	15	19
Coupling block Type A							
Diameter [mm]	Øa	137	147	205	205	235	235
Height [mm]	HKA	60	60	70	75	80	80
Threaded hole		M24	M24	M27	M24	M27	M27
Length of thread [mm]		45	45	45	45	45	45
Number of threaded holes		4	6	6	9	12	12
Coupling block Type B							
Diameter [mm]	Øa	137	147	205	205	235	235
Height [mm]	HKB	60	65	70	75	85	85
Hole for coupling bolt	Ø	25	25	28	25	28	28
Number of holes		4	6	6	9	12	12
Coupling bolts (cylindrical bolts)							
Number of bolts	Stk.	4	6	6	9	12	12
Bolt dimension	Ø	M24×160	M24×160	M27×170	M24×180	M27×180	M27×180
Spacing pipe							
Number of pipes	c	4	3	3	3	3	3
Length [mm]	d	55	50	55	60	50	50
Inner diameter [mm]	Øi	24.5	24.5	27.5	24.5	27.5	27,5
Wall thickness [mm]		2	2	2	2	2	2
Cover box							
Inner diameter [mm]	Øe	147	157	215	215	245	245
Length inside [mm] (fixed coupling)	f	204	204	224	239	244	244
Length [mm] (movable coupling)	g	= f + 1.15 × ΔL + 30 (where ΔL … elongation)					
Length of trumpet (after mounting on anchorplate) [mm]	Lt	250	310	650	600	665	615

VBT-KI 4 to 19	Annex A3
Product description Technical data of the couplings	

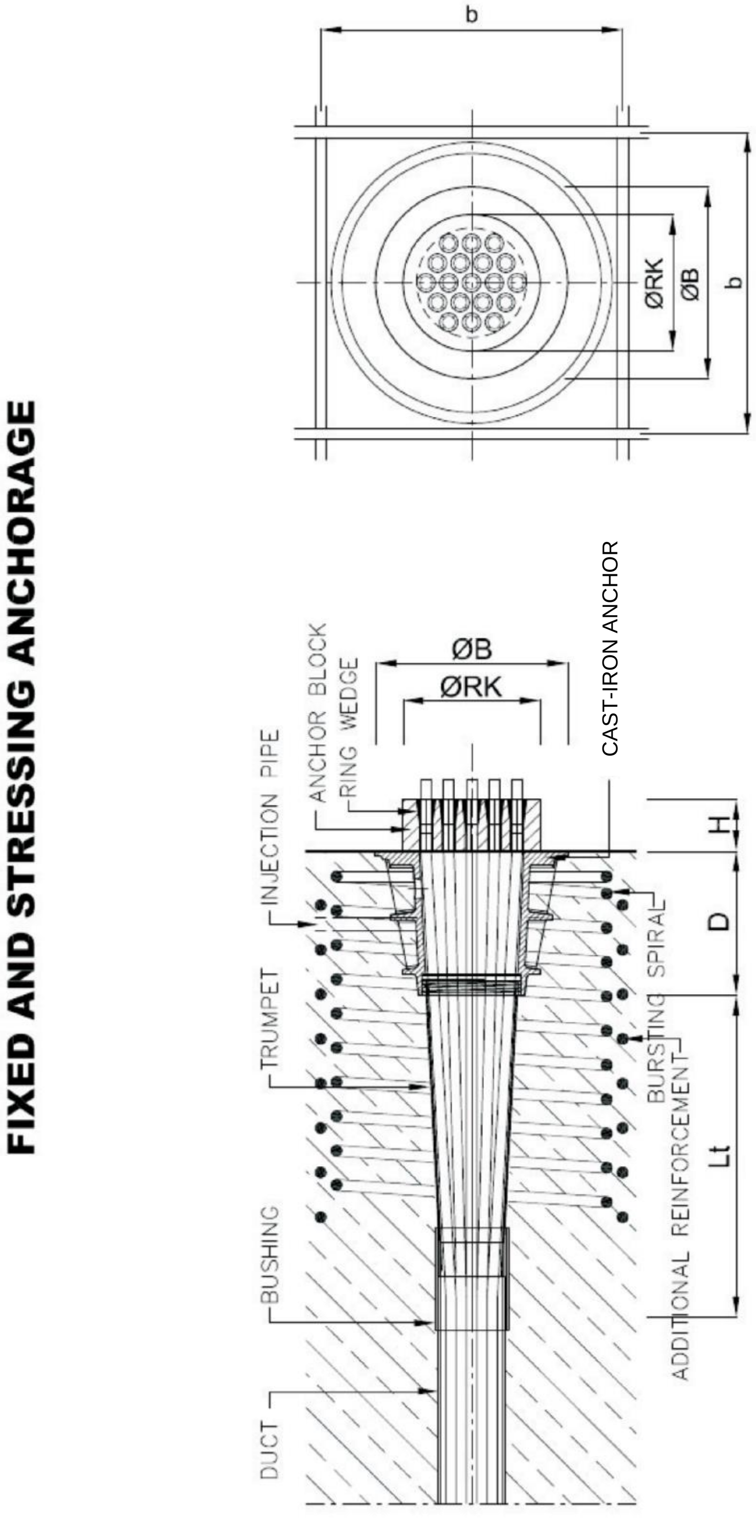


VBT-KI 4 to 19	Annex A4
Product description Plate anchor – fixed and stressing anchorage	

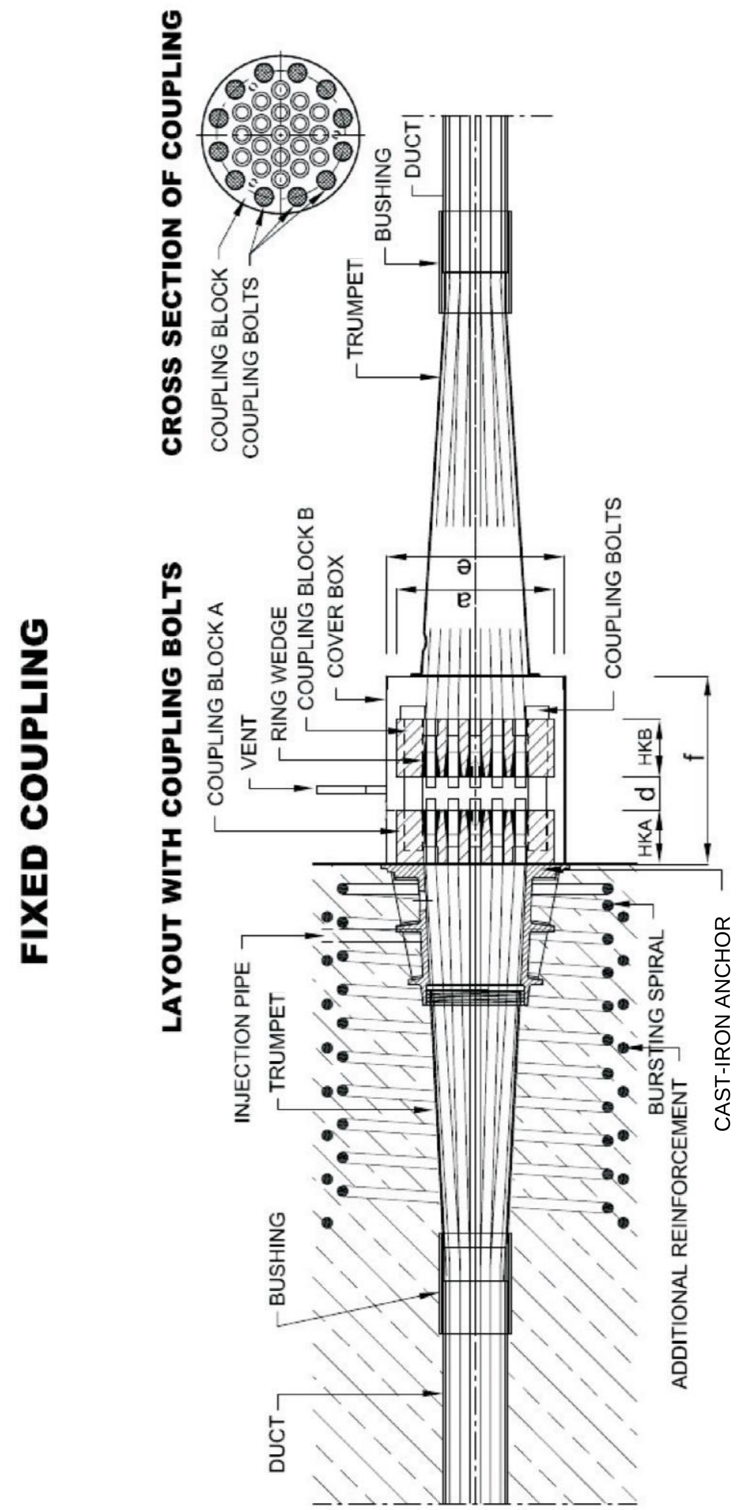
English translation prepared by DIBt



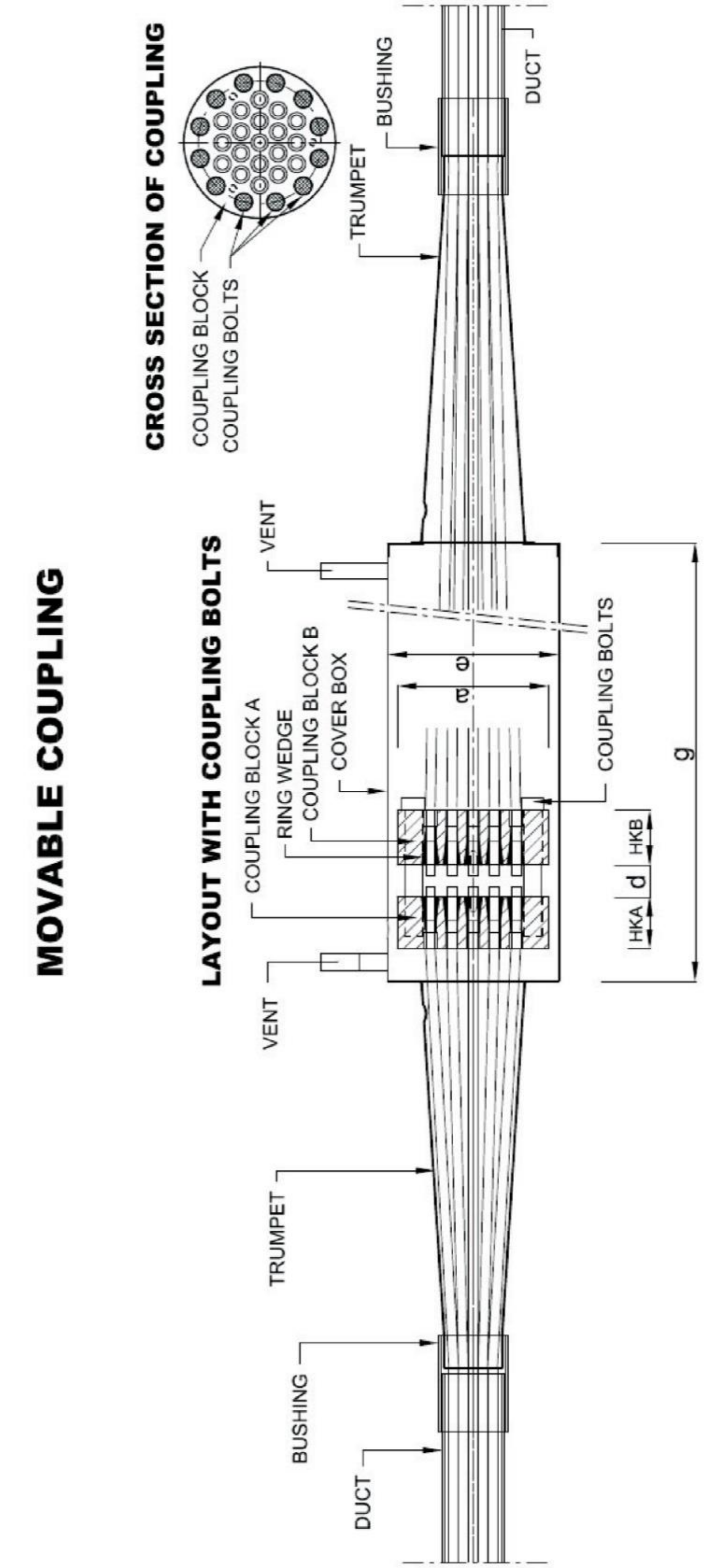
VBT-KI 4 to 19	Annex A5
Product description Plate anchor - fixed coupling	



VBT-KI 4 to 19	Annex A6
Product description Cast-iron anchorage – fixed and stressing anchorage	

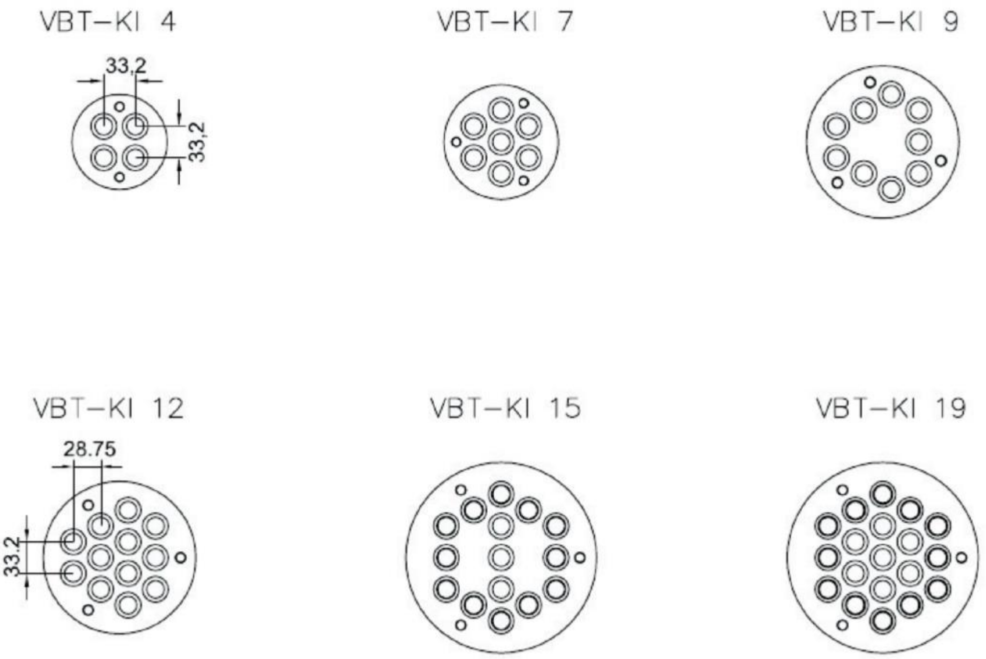


VBT-KI 4 to 19	Annex A7
Product description Cast-iron anchorage – fixed coupling	

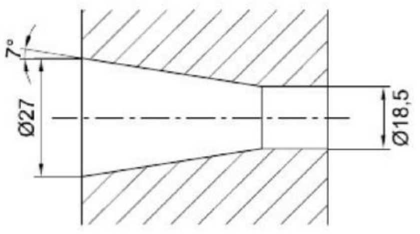


VBT-KI 4 to 19	Annex A8
Product description Movable coupling	

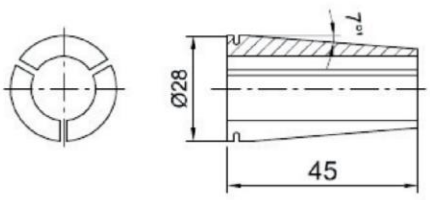
ANCHOR BLOCKS - TEMPLATE OF DRILLING



CONICAL DRILLING



RING WEDGE



VBT-KI 4 to 19	Annex A9
Product description Anchor blocks and ring wedge	

Dimensions and properties of the strands

Designation	Symbol	Unit	Value
Tensile strength	R_m / f_{pk}	MPa	1770 or 1860
Strand			
Nominal diameter	d_p	mm	15.7
Nominal cross section	A_p	mm²	150
Nominal mass	M	g/m	1172
Surface configuration	-	-	plain
Strength at 0.1%	$f_{p0.1k}$	MPa	1520 or 1600*****
Strength at 0.2%	$f_{p0.2k}$	MPa	1570 or 1660
Modulus of elasticity	E_p	MPa	≈ 195.000
Individual wires			
External wire diameter	d	mm	5.2 ± 0.04
Core wire diameter	d'	mm	1.02 to 1.04 d

***** If admissible in the place of use, strands with higher characteristic yield stresses might be used, but not more than $f_{p0.1k} \geq 1560$ MPa (Y1770S7) or 1640 MPa (Y1860S7).

As long as prEN 10138-3:2009-08 has not been adopted 7-wire strands in accordance with national provisions and with the characteristics given in the table above shall be used.

Technical cornerstones

1 Intended use

The Post-Tensioning System is assumed to be used for the prestressing of structures of normal-weight concrete with internal bonded tendons.

Categories of use according to type of tendon and material of structure:

- Internal bonded tendon for concrete and composite structures
- For special structures according to EN 1992, EN 1994 and EN 1996.

The structural members are to be designed in accordance with national regulations.

2 Methods of verification

2.1 General

The structural members (normal-weight concrete) prestressed by means of the VBT-KI Internal Bonded Strand Post-Tensioning System have to be designed in accordance with national regulations.

If VBT-KI Internal Bonded Strand Post-Tensioning system is used in masonry structures, the anchorage has to be carried out by a concrete transmitting block. The dimensions of the transmitting concrete block shall be at least in accordance with this ETA. Load transmission into the masonry has to be verified using a minimum structural strength of 1.1 F_{pk}. Additional national provisions valid in place of use, e.g. for the tendon path, corrosion protection etc. should be considered.

2.2 Tendons

Prestressing and over-tensioning forces are specified in the respective provisions.

The maximum force P_{max} applied to a tendon shall not exceed the force $P_{max} = 0.9\ A_p\ f_{p0.1k}$ laid down in Table B1 (150 mm²).

The value of the initial prestressing force $P_{m0}(x)$ immediately after tensioning and anchoring shall not exceed the force $P_{m0}(x) = 0.85\ A_p\ f_{p0.1k}$ laid down in Table B1 (150 mm²).

Overstressing is specified in the respective national regulations.

The number of strands in a tendon may be reduced by leaving out strands lying symmetrically in the wedge plate (maximum four strands). The provisions for tendons with completely filled wedge plates (basic types) also apply to tendons with only partly filled wedge plates. Short pieces of strands with ring wedges have to be pressed into the cones not filled to assure a sufficient bending stiffness of the wedge plates. The admissible prestressing force is reduced per strand left out as shown in Table B2.

Table B1: Maximum prestressing forces [1)] for strands with A_p = 150 mm²

Tendon designation	No. of strands	Cross section area A_p [mm²]	Prestressing force Y1770S7 $f_{p0.1k} \geq 1520$ MPa		Prestressing force Y1860S7 $f_{p0.1k} \geq 1600$ MPa	
			$P_{m0}(x)$ [kN]	P_{max} [kN]	$P_{m0}(x)$ [kN]	P_{max} [kN]
P 4	4	600	775	821	816	864
P 7	7	1050	1357	1436	1428	1512
P 9 / M 9	9	1350	1744	1847	1836	1944
P12 / M 12	12	1800	2326	2462	2448	2592
P 15 / M 15	15	2250	2907	3078	3060	3240
P 19 / M 19	19	2850	3682	3899	3876	4104

Table B2: Reduction of the prestressing force [1)] when leaving out one strand

A_p [mm²]	Y1770S7		Y1860S7	
	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]	$\Delta P_{m0}(x)$ [kN]	ΔP_{max} [kN]
150	194	205	204	216

[1)] The forces given in tables B1 and B2 are maximum values based on $f_{p0,1k}$ = 1520 MPa or 1600 MPa. The actual prestressing forces to be used shall be taken from the national rules in force at the place of use. If permitted at the point of use, prestressing steel strands with higher characteristic yield strengths may be used, but with a maximum of $f_{p0,1k}$ = 1560 MPa (Y1770S7) or 1640 MPa (Y1860S7). In this case, the prestressing forces of tables B1 and B2 may be multiplied by the Factor ($f_{p0,1k}$ / 1520) or (fp0.1k / 1600) can be increased. Compliance with the stabilization and crack width criterion was demonstrated in the load transfer test at a load level of 0.80 F_{pk}.

2.3 Radius of curvature of the tendons in the structure

According to EAD 160004-00-0301 the following radii of curvature are indicated as performance (at the place of use it must be checked whether they are permissle).

$$R_{min} = \frac{2 \cdot F_{pm0} \cdot d_{strand}}{p_{R,max} \cdot d_{duct,i}} \geq 2{,}50\ \text{m} \qquad (1)$$

where

R_{min}	minimum radius of curvature in [m]
F_{m0}	Prestressing Force of tendon = 0.85 A_p $f_{p0.1k}$ in [kN]
d_{strand}	strand diameter in [mm]
$p_{R,max}$	maximum pressure under the strand ($p_{R,max}$ = 130, 150 or 230 kN/m)
$d_{duct,i}$	inner duct diameter in [mm]

The minimum radius of curvature R_{min} shall be given with an accuracy of 0.1 m (shall be rounded up).

Table B3: Minimum radius of curvature with a maximum pressure $p_{R,max}$ of 130 kN/m

Tendon designation	**Inner duct diameter $d_{duct,i}$ [mm]**	**Minimum radius of curvature R_{min} [m]**	
		A_p = 150 mm²	
		Y1770S7	**Y1860S7**
P 4	45	4,20	4,40
P 7	60	5,50	5,80
P 9 / M 9	65	6,50	6,90
P12 / M 12	75	7,50	7,90
P 15 / M 15	85	8,30	8,70
P 19 / M 19	90	9,90	10,50

Table B4: Minimum radius of curvature with a maximum pressure $p_{R,max}$ of 150 kN/m

Tendon designation	**Inner duct diameter $d_{duct,i}$ [mm]**	**Minimum radius of curvature R_{min} [m]**	
		A_p = 150 mm²	
		Y1770S7	**Y1860S7**
P 4	45	3,70	3,80
P 7	60	4,80	5,00
P 9 / M 9	65	5,70	6,00
P12 / M 12	75	6,50	6,90
P 15 / M 15	85	7,20	7,60
P 19 / M 19	90	8,60	9,10

Table B5: Minimum radius of curvature with a maximum pressure $p_{R,max}$ of 230 kN/m

Tendon designation	**Inner duct diameter $d_{duct,i}$ [mm]**	**Minimum radius of curvature R_{min} [m]**	
		A_p = 150 mm²	
		Y1770S7	**Y1860S7**
P 4	45	2,50	2,50
P 7	60	3,10	3,30
P 9 / M 9	65	3,70	3,90
P12 / M 12	75	4,30	4,50
P 15 / M 15	85	4,70	5,00
P 19 / M 19	90	5,60	5,90

2.4 Concrete strength

Concrete complying with EN 206-1:2001, EN 206-1/A1:2004 and EN 206-1/A2:2005 shall be used. At the time of transmission of the full prestressing force to the concrete member, the mean concrete strength of the normal weight concrete in the anchorage zone shall be at least $f_{cmj,cube}$ or $f_{cmj,cyl}$ according to Table B6 and the Annex A2. The mean concrete strength ($f_{cmj,cube}$ or $f_{cmj,cyl}$) shall be verified by means of at least three specimens (cube with the edge length of 150 mm or cylinder with diameter of 150 mm and height of 300 mm), which shall be stored under the same conditions as the concrete member, with the individual values of specimens not differ no more than 5 %.

Table B6: Necessary mean concrete strength f_{cmj} of the specimens at time of prestressing

$f_{cmj,cube}$ [MPa]	**$f_{cmj,cyl}$ [MPa]**
30	24
37	30

For partial prestressing with 30 % of the full prestressing force the minimum value of the concrete compressive strength to be proved is 0.5 $f_{cmj,cube}$ or 0.5 $f_{cmj,cyl}$; intermediate values can be interpolated linearly.

2.5 Centre and edge distances of the tendon anchorages, concrete cover

The centre and edge distances of the tendon anchorages shall not be less than the values given in the Annex A2 depending on the actual mean concrete strength.

The values of the centre or edge distances of the anchorages given in the Annex A2 may be reduced in one direction up to 15 %, however, not to a lesser value than the minimum distance between the additional reinforcing bars or the external diameter of the helix plus 2.0 cm. In this case the centre and the edge distances in the other direction shall be increased for keeping the same concrete area in the anchor zone.

All centre and edge distances have only been specified in view of load transfer to the structure; therefore, the concrete cover given in national standards and provisions shall be taken into account additionally.

The concrete cover may under no circumstance be less than 20 mm nor smaller than the concrete cover of the reinforcement installed in the same cross section. The concrete cover of the anchorage should be at least 20 mm. Standards and regulations on concrete cover valid in place of use shall be considered.

2.6 Load transfer in the structural concrete, reinforcement in the anchorage zone

The anchorages (including reinforcement) for the transfer of the prestressing forces to the structural concrete are verified by means of tests.

The resistance to the forces occurring in the structural concrete in the anchorage zone outside (behind) the helix and the additional reinforcement shall be verified. An adequate transverse reinforcement shall be provided here in particular for the occurring transverse tension forces (not shown in the attached drawings).

The reinforcement shall be B 500 B according to DIN 488, the dimensions are given in the Annexes A2 and A4. This reinforcement shall not be taken into account as part of the statically required reinforcement. Existing reinforcement in a corresponding position in excess of the reinforcement required by design may be taken into account for the additional reinforcement. The additional reinforcement shall consist of closed stirrups (stirrups closed by means of bends or hooks or an equivalent method) or of orthogonal reinforcement properly anchored. The stirrups locks (bends or hooks) shall be placed staggered.

In the anchorage zone vertically led gaps shall be provided for proper concreting and compacting.

2.7 Slip at the anchorages

The slip at the anchorages (see section 3.4) shall be taken into account in the static calculation and the determination of the tendon elongation.

2.8 Fatigue resistance

With the fatigue tests carried out in accordance with EAD 160004-00-0301, the stress range of 80 MPa of the anchorages and couplers at the maximum load of 0.65 f_{pk} at 2×10^6 load cycles was verified.

2.9 Increased tension losses at couplers

For verification of crack control and stress ranges, increased tension losses of prestressing forces shall be taken into account at the couplers due to creep and shrinkage of the concrete.

2.10 Couplers

Couplers shall be positioned in straight tendon sections with a straight length of at least 1.0 m at each side. For movable couplers the position and length of the coupler duct shall ensure a movement over the length of at least 1.15 Δl + 30 mm, respectively, where Δl is the maximum elongation length at the time of prestressing at the coupler.

3 Installation

3.1 General

The tendon may be manufactured on the site or in the manufacturing plant (prefabricated tendons). Assembly and installation of the tendons shall only be performed by qualified post-tensioning specialist companies which have the required technical skills and experiences with this VBT-KI Post-tensioning system.

The company's site manager shall have a certificate of the manufacturer certifying that he is instructed by the manufacturer and has the required knowledge and experience with this post-tensioning system. National standards and regulations valid on site shall be considered.

The manufacturer is responsible for informing all parties involved about the use of the VBT-KI strand tensioning system. Supplementary technical documents are issued by the manufacturer if required.

The tendons and the components shall be handled carefully.

3.2 Welding

Welding at the anchorages is only permitted at the following points:

a) Welding of the end of the helix to a closed ring,

b) For ensuring the central position the helix may be attached to the anchor plate by tack welding,

c) Welding on additional reinforcement, e.g. to close the stirrups,

d) Tack welding of trumpet on anchor plate.

After placing the strands in the ducts no further welding shall be performed at the anchorages.

3.3 Installation of the tendon

The central position of the helix or stirrups shall be ensured by tack welding (if materials are suitable for welding) to the anchor plate or the anchor body or other appropriate mountings. The anchor plate or anchor body and the anchor block shall be aligned perpendicular to the axis of the tendon.

The tendon shall be placed straight forward the first meter at the anchorage. The bushing connection between trumpet and duct shall be sealed carefully by adhesive tape in order to prevent the penetrating of concrete.

3.4 Wedging force, slip at anchorages, wedge securing and corrosion protection compound

The ring wedges of all anchorages (fixed anchorages and couplers), which are no longer accessible during tensioning, shall be secured by means of pre-wedging with 1.1 $P_{m0}(x)$ during installation. In the case of pre-wedging no slip shall be taken into account for the determination of elongation.

Pre-wedging is not necessary if ring wedges of fixed anchorages or couplers are secured by retainer discs. In this case a slip within the anchorage shall be taken into account for the determination of elongation:

– Fixed anchorage and fixed coupler 6 mm,

– Movable coupler 12 mm.

At stressing anchorage the slip of the ring wedge is 6 mm and shall be taken into account for the determination of elongation. The slip is measured at the measuring marks, which placed on the strand behind the anchorage. The slip of the ring wedges is 1 mm smaller as the slip of the strand.

During installation of wedges into the cones all relevant surfaces and clearances shall be greased with corrosion protection grease. The corrosion protection grease shall comply with EAD 160027-00-0301. Before pouring of concrete, the wedge plates of the not accessible fixed anchorages shall be sealed with a grout ventilation cap.

3.5 Tensioning and stressing records

3.5.1 Tensioning

At time of stressing the minimum mean concrete strength shall comply with the values given in Annex B1, section 2.4.

It is admissible to restress the tendons by releasing and re-using the ring wedges. After restressing and anchoring, wedge marks on strands resulting from first stressing shall be moved to the outside by at least 15 mm.

The minimum straight length for tensioning behind the anchorages (strand protrusion) depends on the jack which is used on site. All strands of a tendon shall be stressed simultaneously. This can be done by centrally controlled individual jacks or by a bundle jack.

3.5.2 Stressing record

All stressing operations shall be recorded for each tendon. In general, the required prestressing force shall be achieved. The elongation is measured and compared with the calculated value.

If during tensioning the difference between measured and calculated elongation or tensioning force is more than 5 % for the sum of all tendons at the cross or 10 % for a single tendon of the calculated value then the engineer shall be informed and the causes shall be found.

Local standards and national regulations valid in place of use shall be considered.

3.5.3 Prestressing jacks and space requirements, safety-at-work

For stressing, hydraulic jacks are used. Information about the stressing equipment has been submitted to Deutsches Institut für Bautechnik.

To stress the tendons, minimal clearance directly behind the anchorages according to dimensions given by the manufacturer shall be considered.

The safety-at-work and health protection regulations shall comply with.

3.6 Grouting

Grouting procedures shall be carried out in accordance with EN 446:1996. Normally, duct shall not be rinsed with water. The grouting speed shall be in the range between 3 m/min and 12 m/min.

The length of a grouted section shall not exceed 120 m. When exceeding this tendon length, additional grouting openings shall be provided.

Vents on the ducts shall be provided at both ends and at the points of the tendon where air or water may accumulate. In the case of ducts of considerable length, vents or inlets may be required at intermediate positions.

Surveillance according to EN 446:1996 shall be carried out.

Local standards and national regulations valid in place of use shall be considered.

4 Packaging, transport and storage

The components and the tendons shall be protected against moisture and staining. The tendons shall be kept away from areas where welding procedures are performed.

For transport and handling of the strands, the provisions of the strand manufacturer shall be observed.

During transport the smallest admissible diameter of curvature of tendons with or without duct is 1.65 m.

Technical description

1 Tendons

As prestressing steel 7-wire strands Y1770S7 or Y1860S7 of nominal diameter 15.7 mm (0.62“), nominal cross section 150 mm², are used.

The tendons are used for internal bonded strand post-tensioning. They can be tensioned on a single or on both anchorages. If tensioned on a single end, the anchorage will be assembled and the ring wedges fixed to the anchor block by strong hitting using impact sleeve.

The coupling can either be a fixed coupling or a movable coupling. Fixed couplings are used to connect to a finished construction stage. After stressing and mostly grouting the tendon, the tendon of the second construction stage is connected to the first one. The movable coupling is needed to extend the total length of the non-tensioned tendon.

At fixed anchorages or coupling blocks (type B), ring wedges will be secured by a wedge retainer disc or are tightened by a hydraulic jack with a pre-wedge lockup force of 1,1 $P_{m0}(x)$ prestressing force. If the ring wedges will be secured by a retainer disc or will be fixed by simple strong hitting with a tube, the calculated elongation must be increased by 6 mm at fixed anchorages and fixed couplings, and by 2 × 6 = 12 mm at movable couplings.

It is possible to couple tendons made of 4, 7, 9, 12, 15 and 19 strands. Couplings are obtained by coupling bolts. To provide an equal force distribution along all bolts in the coupling, the bolts must be tightened to the same torque using a torque wrench.

2 Anchorage

The anchorage consists of a steel anchor block where tendons fit with ring wedges into conical drillings parallel to the axis of the tendons. The drillings are placed in a grid pattern in the anchor block.

The anchor block is mounted on an anchor plate or a cast-iron anchor body to transfer the force into the surrounding concrete. The transition from tendon to the anchorage is done by a trumpet-like widened pipe. To reinforce the concrete behind the anchor plate against splitting tension a combination of helix and additional reinforcement is used.

Fixed anchorages which are set in concrete must be tightened against intrusion of concrete through free spaces in the ring wedges. Tightening can be done either using a protection cap or tightening bands (Densoband). The ventilation during grouting of the prestressed system is performed by a vertically mounted ventilation pipe (plastic), which is connected to the upper side of the trumpet or the cast-iron anchor.

3 Production

The stressing tendons can be produced either in factory or on site. Generally tendons are delivered by the strand manufacturer to the site on coils and in long length, will be cut on site to the final length and directly inserted into the duct. It is also possible to pre-cut the strand in factory to the final length.

4 Ducts

As ducts steel strip sheaths according to EN 523:2003 or corrugated plastic ducts, which meets the requirements of EAD 160004-00-0301 section 2.2.10 and comply with the applicable regulations at the place of use. Plastic ducts and the associated boundary conditions are not regulated by these ETA.

All connections and joints are to be tightened by sealing band.

5 Stressing

Stressing is done by special jacks, which also press in the ring wedges. While reducing the prestressing force in the jack, the tendon pulls the ring wedges into the anchor block (value of the wedge slip). Corrosion protection grease is applied to the conical drillings in the anchor block. To check the elongation value, single strands are marked and changes are measured. The wedge slip at anchorages is 6 mm.

Prestressing force is determined using the calibration curve of the jack. The loss in tensioning force, in the area of the anchorage, is included in the calibration curve, too.

The values have to be recorded in the stressing protocol and be compared to the analytical values.

6 Grouting

Grout material is pressed into the injection pipes until grouting material of same consistency drops out of the other end of the tendon. Specific regulations of EN 445:1996, EN 446:1996 and EN 447:1996 are decisive for grouting of tendons using cement grout. The results of grouting need to be recorded into the grouting protocol.

Time independent losses of prestressing force

Losses of the prestressing force due to friction and wobble effects

The losses of the prestressing force due to friction and wobble effects may normally be determined in the calculation by using the friction coefficients μ and the unintentional angular displacement k (wobble coefficient) given in Table C1. The values μ and k depend on the given duct dimensions and the maximum distances between the tendon supports.

Table C1: Friction and wobble effects for tendons with steel ducts

Tendon designation	**Inner diameter of duct d_H [mm]**	**Friction coefficient μ [rad^{-1}]**	**Wobble coefficient k [°/m]**	**Distances between tendon supports [m]**	**Friction losses $\Delta P_{\mu A}$ [%]**	
					Stressing anchorage	Movable coupler
P 4	45	0.20	0.3	0.9	1.3	1.4
P 7	60	0.20	0.3	1.1	1.1	1.4
P 9 / M 9	65	0.20	0.3	1.3	0.7	1.4
P 12 / M 12	75	0.20	0.3	1.5	0.7	1.1
P 15 / M 15	85	0.20	0.3	1.5	0.8	1.6
P 19 / M 19	90	0.20	0.3	1.5	0.8	1.6

The given values of k apply only if the strands are in the ducts at time of concreting.

If the strands are installed after concreting, the given values k shall only be used in the calculation if the ducts are adequately stiffened during concreting, e.g. by means of PE-pipes, or if reinforced ducts are used in connection with smaller distances between tendon supports.

For the determination of strains and forces of prestressing steel friction losses $\Delta P_{\mu A}$ in the active anchorage zone shall be taken into account according to Table C1.

Codes and references

prEN 10138-3: 2009	Prestressing steels – Part 3: Strand
EAD 160004-00-0301: 2016	Post-tensioning kits for prestressing of structures
EAD 160027-00-0301: 2016	Special filling products for post-tensioning kits
EN 10025-2: 2004	Hot rolled products of structural steels – Part 2: Technical delivery conditions for non-alloy structural steels
EN 10083-1: 2006	Steels for quenching and tempering – Part 1: General technical delivery conditions
EN 10204: 2004	Metallic products – Types of inspection documents
EN 10277-2: 2008	Bright steel products – Technical delivery conditions – Part 2: Steels for general engineering purposes
DIN EN 1561: 2012	Founding – Grey cast irons
EN 445: 1996	Grout for prestressing tendons – Test methods
EN 446: 1996	Grout for prestressing tendons – Grouting procedures
EN 447: 1996	Grout for prestressing tendons – Specification for common grout
DIN 488-1: 2009	Steel for concrete – part 1: Steel grades, characteristics, marking
EN 523: 2003	Steel strip sheaths for prestressing tendons – Terminology, requirements and conformity
ISO 898-1: 2013	Mechanical properties of fasteners made of carbon steel and alloy steel – part 1 Bolts screws and studs with specified property classes – Coarse thread and fine pitche thread
EN ISO 17855-1: 2014	Plastics – Polyethylene (PE) moulding and extrusion materials – Part 1: Designation system and basis for specifications (ISO 17855-1:2014)
DIN EN ISO 4762 -6: 2004	Hexagon socket head cap screws
EN 206-1: 2001	Concrete - Part 1: Specification, performance, production and conformity; German version EN 206-1:2000
EN 206-1/A1: 2001	Concrete - Part 1: Specification, performance, production and conformity; German version EN 206-1:2000 / A1:2004
EN 206-1/A2: 2005	Concrete - Part 1: Specification, performance, production and conformity; German version EN 206-1:2000 / A2:2005